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HUMAN ACCELERATION RESEARCH AT ARMSTRONG LABORATORY, 1973-1993: A DYNAMIC PROCESS

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This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

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13. ABSTRACT *(Maximum 200 words)* The history of disqualified subjects from 1973-1993 at Armstrong Laboratory is presented for both sustained and impact acceleration panels. The screening criteria for candidates, the physician doing the interpretation of the screening examinations, and the type of research being performed all contribute to the disqualification of candidates and subjects. The importance of knowing the impact of these factors on the composition of the panels is stressed as this determines to which target population the research data can be applied. The rational for each disqualification is discussed, demonstrating the variability in each panel physician's clinical judgement in the context of personal bias, the ethical framework surrounding the use of human volunteers, and the existing research environment. Comparisons of the two human volunteer subject panels to each other and other samples of different populations (composite from scientific literature; French, Norwegian, and Netherlands pilots; US Navy subjects) were made using the proportion parameters of various spinal anomalies. Several sources of bias and error were present: 1) variability between raters (radiologists); 2) lack of a standard format for reporting spinal anomalies; and 3) lack of a readily accessible, useable, and representative US Air Force pilot spinal anomaly database.

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PREFACE

The research reported herein covers the Sustained Acceleration Panel and the Impact Acceleration Panel from 1973 to 1993. This was a retrospective study of all qualified and disqualified candidates for both panels. The opinions expressed in this article are those of the authors and do not necessarily reflect policy or opinions of the Department of the Air Force or the Department of Defense. In keeping with the suggestion of Strunk and White (56), the pronoun "he" is used instead of the clumsy "he or she" in reference to both male and female subjects.

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OVERVIEW

This research is based on a retrospective study of the Armstrong Laboratory (AL) Sustained Acceleration Panel (SAP) and Impact Acceleration Panel (IAP). Medical records from 1973 through 1993 were reviewed for medical history and medical screening to include physical examination, EEG, EKG, full spinal x-rays, exercise treadmill test (ETT) and blood chemistry. These criteria have varied slightly over time with most of the changes occurring during 1991 through 1994. This report traces the evolution of the medical screening criteria, analyzes spinal anomalies, analyzes non-spinal anomalies, compares USAF acceleration panels with multiple populations (pilot, subject, normal) and discusses the future of human subject panels. A review of the literature provided data on other subject populations, foreign pilot populations, the normal population, and the process of establishing subject screening criteria. The frequencies of spinal anomalies in several test populations are compared. The results of this study are discussed in light of establishing more comparability between test subjects and pilots and more comparability across pilot populations data bases and methods.

Published Air Force medical examination and standards are used by the authors as a baseline. These standards changed effective 15 November 1994 when AFR 160-43 was replaced by AFI 48-123. There was no significant change in the areas the authors review except for compression fractures as detailed in the text.

EVOLUTION OF HUMAN SUBJECT MEDICAL SCREENING CRITERIA

Introduction

Human acceleration research at Armstrong Laboratory, Wright-Patterson AFB, Ohio, has a distinguished record in gathering data relevant to the aerospace community. In part, this is due to the maintenance of two subject panels for acceleration research; the SAP and the IAP. The criteria for acceptance into one of the panels is fairly straight-forward: one must 1) be a volunteer; 2) pass a series of medical screening tests to include full spinal x-rays, EEG (IAP), exercise treadmill test (SAP), blood screening, and physical examination; and 3) be motivated to be an active participant. These criteria are panel-dependent, with some of them changing with time.

Medical screening requirements are predictated upon preserving the welfare of the subject but must also allow selection of a population similar to the aircrew population (61). The use of humans in more-than-minimal risk research also requires an evaluation of the "benefit-to-risk ratio" (2). This ratio is utilized by the Human Use Review Committee (HURC) to determine whether the subject should participate in a given experiment. Paradoxically, this can run counter to extensive medical screening (41). The paradox occurs because extensive medical screening may result in a subject pool that no longer truly represents the target population. This may reduce the benefit of the research so much that no risk to the subjects could be justified.

This first part of the report traces the history of disqualified subjects from the subject panels at Armstrong Laboratory, formally known as the Harry G. Armstrong Aerospace Medical Research Laboratory, from 1973 to 1993. The screening criteria are major factors in disqualifying subjects and their generation and interpretation will be discussed.

Source of Criteria

Medical screening criteria for human subjects are documented in the Generic Protocol for each panel (SAP, IAP). These documents specify the boundaries of acceleration exposure to which humans may be exposed and/or the limits of a particular acceleration device. They also specify the medical criteria to be a member of a specific panel (see Table 1) (19,20). The medical standards are those of the USAF Flying Class II physical examination IAW AFR 160-43. Prospective subjects do not have to pass every standard, but this examination documents the subject's medical condition so that the panel physician and appropriate consultants may determine the candidate's appropriateness for acceleration exposure (19,41).

TABLE 1: MEDICAL SCREENING REQUIREMENTS FOR IMPACT ACCELERATION SUBJECTS

MEDICAL SCREENING REQUIREMENTS	INITIAL	ANNUAL	TERMINAL
Physical Examination (SF 88/93) to include visual acuity, audiometry, blood pressure	X	X[1]	X[2]
Routine Blood Work	X	X	X
Urinalysis	X	X	X
Standard 12-lead EKG	X	X[3]	X
Chest X-ray	X		X
Pulmonary Function Tests	X	X	X
Electroencephalogram	X		X
Skull and Spine X-rays	X		X
Lateral Cervical Spine full extension, full flexion, neutral	X		X
Pregnancy Test (Female Subjects)	X	X	X

[1]Annual physicals will be long, short, short, similar to flight physicals
[2]Termination physical does not have SF 93
[3]Not done for annual

Medical criteria within the generic protocol are evaluated by the local HURC who recommends approval or disapproval to the Laboratory Commander. The Commander, after signing approval, forwards the document to USAF Headquarters for their review and approval. Any specific protocol operating within the boundaries of the approved general protocol needs only Laboratory Commander approval.

Mechanism For Change to Criteria

In order to change, delete, or add to any existing medical screening criteria, the proposed changes are presented to the HURC. These changes may be initiated by anyone (e.g., physician, researcher, etc.). However, the chiefs of the branch and division where panels are utilized have responsibility for reviewing any changes affecting the panel prior to their submission to the HURC (28). The HURC reviews any changes in light of the risk-to-benefit ratio, proper informed consent, and appropriate project standards (2).

Factors Influencing Change to Criteria

Medical screening criteria may change as new technologies become available, an existing standard is refined, or a current methodology is proven to have poor predictive capability for the targeted medical parameter within the subject population. An example of a new technology applied to human research is magnetic resonance imaging (MRI). An initial apparisal would seem to validate the use of MRI in screening given its proven record in clinical medicine. Upon further investigation, problems emerge because the population of interest is asymptomatic, and screening may prevent the subject panel from representing the target population. This type of evaluation may cause the HURC to recommend disapproval of the change in screening protocol because it may result in little derived benefit because subject data would not be applicable to the pilot population (41). In addition, in a population with low prevalence of a given condition, a higher proportion of the positive results will be false positives (i.e., low predictive value) (36). As part of the ethical design within the system, the HURC's recommendation for disapproval can not be overturned by the Laboratory Commander. Conversely, the Commander can disapprove a recommendation for approval from the HURC (2).

The refining of an existing standard was done with the series of 14 spinal x-rays. The cervical series of hyperflexion, hyperextension, and neutral were added. This expansion was intended to enhance safety of the subjects on the impact panel who were volunteers under a protocol investigating the effects of variable helmet weight and center-of-gravity (CG) helmets.

An example of a poorly predictive test being removed from the medical screening crtieria is the exercise treadmill test (ETT) for the IAP. A case was presented to remove the ETT using the recommendations from the USAF School of Aerospace Medicine (Letter from USAFSAM, "Cardiovascular Screening for Human Experimentation Panel Subjects," 6 Oct 87). This was approved at the local level up through Air Force Headquarters.

Interpretation of Screening Criteria

The actual disqualifying parameters derived from screening tests are not specified within the Generic Protocols. These decisions are left to the panel physicians in conjunction with appropriate consultations. A baseline for standards is the Flying Class II physical examination, but this has been modified to reflect the needs and interests of the Laboratory (e.g., vision standards) (61). A specific protocol may require an additional screening of existing panel members, so that only a select few from the panel may participate (e.g., anthropometric considerations, gender, or vision).

It has been the practice of this laboratory to allow panel physicians to follow their own musculoskeletal criteria for disqualifying individuals (e.g., degree of scoliosis, existence and number of Schmorl's Nodes, and degenerative changes). Hearon and Raddin (23) advocated a 10° limit on scoliosis which has been followed by some of the succeeding panel physicians even though the pilot candidate disqualification limit has been 20° (recently increased to 25°). This variability in what determines disqualifications has affected the composition of each panel.

The synopsis of candidate screening from 1973 to 1993 is presented in Table 2. The majority of disqualified candidates were from the impact facility (1989-1992). Although there appears to be more concern over the musculoskeletal status of impact candidates due to the nature of G exposure (i.e., 10° scoliosis criteria (23)), physician mind-set is also a major factor in deciding who is qualified and disqualified. Whether a conservative approach to screening criteria is taken for the protection of the subjects or the physician, the end result is the same. In the authors' opinion both modes were in operation during the 1989-1992 time frame. However, this time frame also covered the protocols investigating the variable helmet weight and CG resulting in the addition of three cervical x-rays for screening. Only one subject was disqualified through the use of these new screening x-rays with the finding of "slight anterior displacement of C_4 over C_5." Even though some literature supports pilots still flying with spondylolisthesis (SLL) with one pilot ejecting without any further slippage (17,16), these reports only dealt with lumbar SLL. Excluding this case, of the initial screening disqualifications due to asymptomatic spinal anomalies

from the impact panel candidates, 15 of 15 candidates would have been qualified by the present impact panel physicians. The next two chapters examine specific instances of disqualification and indicate a number of cases where disqualified subjects would not have been disqualified by the current panel physicians.

The key question is whether the changing composition of the panel, due to varying levels of conservatism by the panel physicians, effects the data being generated in research in such a way that it cannot be applied to pilots (41). This is especially relevant as the environment pilots operate within becomes more severe (e.g., performance envelope of new generation aircraft and corresponding increases in ejection system performance).

Conclusion

The history of subject screening for both the sustained and impact acceleration panels at Wright-Patterson AFB presents a microcosm of the dynamics of any large organization. There are standing guidelines on how to do business, but it is the individuals within the organization who provide the nuances to their interpretation. As these individuals change, so may the direction of the organization. For instance, the next two chapters examine the disqualification of subjects on both panels and demonstrate a number of cases where the current panel physicians would not have disqualified these subjects.

TABLE 2: Candidate Screening Data 1973-1993

	Centrifuge	Impact
Candidates	132[1]	195
DQ[2]	7 (5%)	36[3] (18%)
Q[4]	125 (95%)	159 (82%)
% Musculoskeletal DQ	2 (29%)	24 (73%)
DQ from 1973-88	7 (100%)	10 (28%)
DQ from 1989-92	0 (0%)	26 (72%)

Notes:

[1]Includes 6 individuals who were on both panels

[2]Disqualified for panel

[3]Includes 2 individuals with no specific documentation as to DQ rationale; these 2 are not included in % Musculoskeletal DQ determination

[4]Qualified for panel

SPINAL LESION DISQUALIFICATIONS

Introduction

The rationale for disqualifying candidates/subjects from the Human Acceleration Panels of the Armstrong Laboratory, Wright Patterson AFB, for spinal-related conditions from 1973 to 1993 is discussed. In some cases the candidates had conditions which precluded them from being accepted as subjects, while in others, previously qualified subjects were determined to be unfit for further hazardous duty.

Only two of the seven candidates/subjects disqualified (DQ) from the centrifuge (sustained acceleration) were excluded due to spinal anomalies, a rate of 28 percent. For impact acceleration, 24 of 34 (71 percent) candidates/subjects were DQ due to spinal anomalies. Table 2 breaks out the total number of candidates, those DQ and the time frame of the DQ. Table 3 provides the categories of anomalies with the number of DQ candidates/subjects as well as the number of DQ individuals using the criteria of the current panel physicians (e.g., AFR 160-43). The only real agreement occurs in the categories of clinical impression and fractures. The other categories of anomalies are associated with varying degrees of hazard with regard to acceleration exposure. However, most of these viewpoints are opinions without adequate supporting documentation. The following are examples.

Thoracic Kyphosis

One subject was DQ after a yearly x-ray indicated 30° thoracic kyphosis, 11° thoracic levoscoliosis, and mild degenerative changes T_8-T_{12}. Based on extensive radiographic evaluation of their pilot population, DeLahaye advocated a disqualification standard of > 50° of thoracic kyphosis (10). As stated in the subject's medical research record, there was no hard data precluding further participation except for the traditional conservative approach to subject safety. No mention was made as to any changes over time from initial radiographic evaluation.

Scoliosis (with Degenerative Changes, Spondylolysis, Fusion Defects)

There were nine individuals with scoliosis, either isolated or combined with other anomalies. The USAF standard is < 25° for scoliosis (as measured by the Cobb method). There were no scoliotic curves approaching 25°. The French have more stringent criteria; $\leq$ 15° for combat aircraft and helicopter pilots (10). None of the individuals disqualified were > 15°. Froom followed 21 pilots in order to determine the natural history of spondylolisthesis (SLL) (defined as displacement of any vertebra of at least 10 percent of the diameter of the adjacent vertebral

TABLE 3: Distribution of Anomalies

Categories of Spinal DQ	#DQ	#DQ by Current Panel Physicians
Clinical impression	4[1]	4
Degenerative changes	5	0
Scoliosis	3	0
Scoliosis/Kyphosis	1[2]	0
Scoliosis/degen. changes	2[3]	0
Scoliosis/spondylolysis	1	0
Scoliosis/fusion defects	1	0
Scoliosis/spondylolysis/ degenerative changes	1	0
Fusion defects	2	0
Spondylolysis/listhesis	2[4]	0
Fracture	2[5]	2
Atlanto-axial fixation	1[2]	0

Note:

[1]3 of the 4 were qualified for acceleration panel prior to being DQ

[2]DQ after being on acceleration panel

[3]1 individual had a mucocele retention cyst in inferior maxillary sinus

[4]1 individual was DQ after evaluation by additional c-spine x-rays

[5]1 individual incurred injury after qualified for acceleration panel, other individual had a history of wedge compression fracture at T_{12}

body) (17). Of the 12 pilots with SLL and low back pain (LBP), 4 had recurrent single episodes of acute LBP but all remained active and continued to fly over the follow-up period. None of the 9 pilots who had SLL discovered on routine x-ray examination developed LBP over the follow-up period. The authors concluded that pilots with SLL can fly with minimal risk of morbidity and loss of flight time. They advised caution on their interpretation of the data until further studies are done.

Andersson presented the following information on the prevalence of disc degeneration (4): 1) clear association between increasing age and progressive degeneration of the spinal structures; 2) sex distribution varies with study performed; 3) most investigators agree that disc degeneration is more severe and starts earlier at the L-4 and L-5 levels while L-2 and L-1 discs are less frequently degenerated; 4) there is a well-known problem of defining disc degeneration using radiographs (narrowing of disc space is usual indicator, but is already a sign of advanced disc degeneration and is difficult to detect until quite severe); 5) significant disc degeneration is observed in most spines by 4th decade and may be present as early as the 3rd; and 6) fifth cervical disc is most frequently degenerated, followed by C-4 and C-6.

Gillen and Raymond compared high performance fighter pilots with an age-matched control population looking at progressive cervical osteoarthritic changes (21). An interesting observation was that pilots only volunteered after being assured that the medical data obtained would be used for statistical purposes only and would not allow identification of individual participants. Findings were discussed with each pilot at the conclusion of their participation in the study. The pilot group at 30-39 showed significantly more osteophytic spurring at both C_5 and C_6 than did either of the control groups ($p < .05$, t test, 2 tail). At the $C_{4/5}$ and $C_{5/6}$ level there was a strong significant difference between pilots and controls of all groups ($p < .01$) demonstrating more disc space narrowing.

DeLahaye et al., after extensive radiographic studies, established fitness criteria for combat aircraft, helicopter, and transport aircraft pilots (10). Transitional lumbosacral anomalies, dissolution of the isthmus (except with spondylolisthesis and slippage more than 1 cm), and congenital blocks are all fit for combat aircraft duty. Major congenital or acquired anomalies are unfit.

Fracture

There were two cases of compression fracture. One candidate had a history of a wedge compression fracture of T_{12}; there was no mention of the percent of vertebrae involved. If the compression

involves less than 25 percent of a single vertebrae, it is waiverable (by USAF standards) if healed completely and asymptomatic. (Standard during time frame of injury. New medical standards AFI 48-123 changed to "compression fractures more than 25% of more than a single vertebrae may be considered for categorical IIB waiver.") Given the stress on safety in human research, it is probably on the prudent side to disqualify this individual. The other was an active subject who sustained a compression fracture of T_{4-5} from a 10 G vertical drop test and was appropriately disqualified from further exposure.

Clinical Impression

Clinical diagnosis is often the strongest argument and the easiest to defend in removing an individual from hazardous duty. The asymptomatic patient with some type of finding on a screening test is a problem that confounds subject selection as well as pilot screening (60). All of the disqualified subjects were either experiencing pain or had a chronic history of back pain; thus indicating that the presence of acute or chronic pain tips the balance in favor of disqualification.

Conclusion

Of the 26 individuals disqualified for spinal anomalies in the past from both panels, only 6 would have been disqualified by the current panel physicians. There are several reasons why physicians differ on qualification criteria for human acceleration research: 1) familiarization/agreement with the literature; 2) the degree of conservatism in viewing humans in research; and 3) any special research thrust (e.g., variable weight helmet system). In some cases, there are no firm guidelines for disqualification, especially for asymptomatic individuals. The physician's evaluation and treatment of <u>symptomatic</u> conditions is the most important part of the decision to disqualify a subject/candidate. It is also the most consistent among physicians.

NON-SPINAL DISQUALIFICATIONS

Introduction

In this chapter we consider non-spinal and medical-related conditions resulting in disqualification during the years 1973 to 1993. In some cases, the candidate had a condition that precluded acceptance as a subject, while in others, a qualified subject was determined to be unfit for further hazardous duty.

Of the 7 candidates/subjects disqualified from the centrifuge (sustained acceleration), five (71%) were due to non-spinal conditions. For impact acceleration, 12 of 36 (33%) candidates/ subjects were disqualified due to non-spinal conditions. Table 2 breaks out the total number of candidates, those disqualified, and the time frame of the disqualification.

Table 4 provides the categories of non-spinal conditions with the number of disqualified candidates/subjects as well as the number of disqualified individuals using the criteria of the current panel physicians (e.g., AFR 160-43). The key difference between most of the spinal and non-spinal conditions is that the non-spinal tend to be symptomatic. The major exception is the Electroencephalogram (EEG), which may show abnormalities in an otherwise asymptomatic subject (similar to radiographic findings in the spine).

Discussion

The candidates for each panel were not selected at random and are not directly comparable. However, there are valid reasons why more candidates would be disqualified from the impact panel (with a higher percentage of spinal disqualification) than from the sustained acceleration panel. Historically, the impact panel has had more stringent criteria e.g., 10° limit on scoliosis when the AF standard was 20°). Further, the impact subjects tend to undergo more severe stresses on the head and spine, especially in experiments involving head center of gravity and helmet weight changes (23,41).

EEG: The sensitivity, selectivity, and cost effectiveness of the EEG have a controversial history. The Canadian Forces continue to perform screening EEG's on all pilot candidates which are all interpreted by the same neurologist. Candidates with a Type III EEG (specific EEG waveform abnormalities including focal spike discharges or generalized spike and wave discharges) are rejected from pilot training. Despite the low predictive value and substantial manpower requirements, the Canadian Forces continue to perform EEGs due to the potentially catastrophic nature of a seizure in flight (22). A comparison of routine medical examinations performed by twelve air forces showed only two have a requirement for EEGs: Turkey, every three years at their

TABLE 4: Distribution of Medical Conditions

Categories of Medical DQ	#DQ	#DQ by Current Panel Physicians
PVC's at G (centrifuge)	1	0
Onset of Diabetes	1	0
Hematuria[1]	2	2
Pulmonary System		
Spontaneous Pneumothorax	1	1
permanent wheezing, ↓PFT	1	1
Neurological		
abnormal EEG[2]	4	1
hx of LOC (3 min)	1	0
Sliding Hiatal Hernia	1	0
s/p hernia repair[3]	1	0
hx of shoulder dislocation	1	1
Breast implants	1	1
mucocele/polyp retention cyst at inf. maxillary antrum	1	0
Total	16	7

Note:

[1]Both subjects would have been initially DQ as explained in the text (but not necessarily permanently).

[2]The candidate who would have been DQ by us was found to have hydrocephalus and shift of midline structures.

[3]Subject was original DQ from impact panel due to hx of bilateral chondromalacia and a 2 cm cyst in medial femoral condyle, cleared for centrifuge by orthopedics, subsequently DQ from centrifuge for hernia repair and terminated eventually without any g-exposure.

central institution; and Germany, every ten years at their central facility (38). The HURC recommended removal of the EEG as part of the AL subject screening. The Commander approved the recommendation which was sent to Headquarters (USAF), who gave final approval in 1994. It is a well documented phenomenon that even previously healthy subjects are prone to seizures during an episode of G-LOC (G-induced loss of consciousness) (7). It has also been shown that these seizures do not result in neurologic deficits in either the immediate recovery period (14) or the long term (62,63,64).

Most significantly, in a study of 28,658 student aviators in the period 1961 to 1071 (34), only 38 subjects were found to have abnormal EEG's (0.12%). Thirty-one of these were located by 1973 and only one had a seizure. Just 4 of the 28,620 normals (0.014%) had developed clinical seizures. The authors feel that the expenditure of resources expected to detect a seizure disorder in 5 of 28,658 subjects is not justified, given that only 201 impact subjects have been examined at AL in twenty years!

PVC's at G (centrifuge): High sustained Gs are very stressful. Various arrhythmias are anticipated under centrifuge training (55). There is no fixed criterion (in terms of the number of PVC's) for termination of a sustained acceleration run at Armstrong Laboratory, although six per minute is generally accepted as the threshold. At the Brooks AFB centrifuge, the criteria to abort a run have been: 1) frequent (> 5/min) PVC's; 2) multifocal PVC's; 3) paired PVC's; 4) ventricular bigeminy/ trigeminy; 5) ventricular tachycardia; 6) supraventricular tachycardia; and 7) stress-induced bradycardia (61).

The problem of dysrhythmias under G has not been fully studied. Even when a significant dysrhythmia is observed under high sustained G, full evaluation post-run generally does not show any organic etiology (61). Given that the centrifuge is used in an experimental setting, one may advocate protecting the subject at all costs, and thus remove them from the panel. Unfortunately, then, the question of whether dysrhythmias under G are significant compared to those induced by cardiac pathology is never answered. Furthermore, the situation is compounded by the use of pilots in this type of research; pilots will be grounded if they exhibit any of the above-mentioned dysrhythmias. Not only does this obscure any casual relationship, it adds to the reluctance of pilots (who are the subjects of greatest relevance) to participate in research.

Diabetes: The rationale for disqualification is the possibility of loss of consciousness, or reduced situational awareness (due to hypo- or hyperglycemia). However, under the controlled conditions in the laboratory, this is considered very unlikely to present a problem to the subject's safety. The current

physicians would not disqualify a subject who is otherwise capable of performing his duties on the panel.

Hematuria: A subject reporting gross hematuria would be initially suspected, in the absence of any significant history, of having undergone trauma to the kidneys (especially a member of the impact panel). Of course, a variety of conditions including bladder cancer and infectious diseases would have to be considered. Microscopic hematuria would normally be discovered incidentally, or at annual screening. The subject would be temporarily disqualified, and a complete workup started (including serial urinalyses). It would be prudent to temporarily remove the subject from the panel until an attempt was made to ascertain whether the hematuria was associated with acceleration or other genitourinary pathology. If there was no association identifiable, the authors would reinstate the subject (but follow him closely).

One of the two subjects who had been disqualified had been found during initial examination to have gross hematuria. History revealed one previous episode approximately two years prior, which he had ascribed to martial-arts training. It had resolved promptly and not recurred, so he had not sought medical attention. Further workup of the recurrence was initiated, but the subject was then lost to panel follow-up, having been disqualified. The other subject had been on the impact panel for approximately one year and had been found to have microscopic hematuria on routine screening. He reported gross blood on only one occasion (following intercourse). Urology and nephrology workups were unremarkable, and the diagnosis of essential hematuria was made. Due to the panel physician's concern over possible mechanical injury to the kidneys, he was terminated from further exposure.

Pulmonary System: One subject with a history of spontaneous pneumothorax (SP) was disqualified from sustained acceleration runs. It may not be commonly recognized that this disorder has an incidence of 4.3 per 100,000 patient-years, with a 5:1 male:female ratio (which approximates 1 in 500 in males). It occurs most commonly in tall, otherwise healthy males who smoke (47). Furthermore, the rate of recurrence is quite high (30% ipsilateral, 10% contralateral) (65).

Currently in the USAF for an initial pilot physical, a single episode of spontaneous pneumothorax is waiverable, but only after 3 years with no recurrence and no demonstrable pathology (U.S. Air Force Regulation 160-43, p. 57, Section 6/18 (b) 1). Given that (if this patient were a pilot) he would be automatically grounded for 3 years, and the mandate of the HURC to avoid injury to human subjects, it is reasonable to have disqualified this subject from further acceleration studies. It is also arguable, however, that 75% of SP occurs during light activity or at rest,

and not necessarily during acceleration stress (58). The current panel physicians feel that the conservative approach was warranted in this case.

Permanent Wheezing, ↓PFT: This subject was disqualified due to diffuse bronchial wheezing, pulmonary function test (vital capacity 81% predicated), and bilateral crepitus of knee joints. The records contain a statement from the panel physician to the effect that these conditions prohibited his participation on the impact panel, with no further explanation. The primary concern, although unspecified, was probably the fear of lung injury (although no defects were seen on chest radiographs). A secondary problem was the crepitant knees, as extremities also are subjected to large stresses and deflection angles. This subject would also have been disqualified by the current physicians for the same reasons.

History of Loss of Consciousness (3 min): Obviously, an unexplained history of loss of consciousness (LOC) by a pilot is grounds for disqualification. In a test subject it might be of lesser concenr, especially if an attempt to identify the cause has been made. For example, an impact subject in 1993 became diaphoretic, pale, unresponsive (i.e., presyncopal) and bradycardic just prior to this first run. These symptoms resolved immediately on extraction from the sled and placement in Trendelenburg position. Upon investigation he was found to have been breathing in a rapid but shallow pattern due to apprehension. He was run the following day with no further problems; no further workup was performed. Another example (from the centrifuge panel) occurred during an initial orientation run in 1990. The subject was apprehensive and began performing the L-1 straining maneuver at 1.6 Gx, and subsequently lost consciousness. With further instruction, the subject went on to become an outstanding contributor to acceleration research. In the case of the subject disqualified for LOC, there was a history of approximately 3 minutes unconsciousness due to a sports injury two years before. (Many people find it difficult to give accurate estimates of time of LOC). He was not hospitalized, and had no sequelae. He would not be disqualified from acceleration studies by the current impact panel physicians, as long as his skeletal x-rays, EEG, and the remainder of the standard examination were normal.

Sliding Hiatal Hernia: The concern here is apparently that the stomach may be displaced into the thorax during -Gz (eyeballs-up) acceleration. A Type I hiatal hernia is the most common, found in approximately 30% of patients who undergo upper GI series (47). Type I hernias are usually of no clinical significance; most patients with hiatal hernia do not have reflux symptoms (47). They also generally are not found to enlarge (48).

There is a significantly higher risk of incarceration in a Type II (paraesophageal) hernia, however, in one prospective study of 21 patients with an asymptomatic but totally intrathoracic stomach, six died of complications related to the hernia within 2 years (48). It seems clear that surgery would be highly recommended in any patient with a Type II hiatal hernia, which would be at least temporarily disqualifying from the panel. Hernias are disqualifying for Flying Class II and III physicals unless they are small asymptomatic umbilical or hiatal defects (according to AFR 160-43).

In this case, the subject's medical records showed only that he had a "sliding hiatal hernia", with a history of severe recurrent epigastric pain. There was no correlation of the pain with impact exposure, and no documentation of the panel physician's rationale for disqualifying the subject. Unfortunately no further medical records are available.

S/p Hernia Repair: This subject probably would not have been disqualified permanently. He was rejected for the impact panel due to bilateral chondromalacia and bone cysts in the distal femurs. He was initially qualified for sustained acceleration duty; however, he subsequently developed a right inguinal hernia, which required surgical repair, and was suspended from the sustained acceleration panel for one year from the date of surgery. No further entries exist in his panel medical records, so his post-surgery experiences are unavailable. This suspension was a prudent decision in light of the Valsalva-type maneuvers required to sustain blood flow to the brain during high-G. There is also an asymptotic relationship of final wound strength with time; most of the wound strength is achieved in the first 8 weeks or so, but there is a slow and steady rise out to one year and beyond (48).

History of Shoulder Dislocation: This subject, after consultation with an orthopedic surgeon, was limited to suspension and vibration tests only due to his history of bilateral chronic anterior shoulder dislocations. This seems reasonable given the large forces and arm deflections observed in impact acceleration tests.

In general, however, a subject with a history of a dislocated shoulder due to trauma would not necessarily be precluded from participation. A complete evaluation of the affected shoulder by an orthopedic surgeon would be required to confirm that there was no instability of the joint which might result in a dislocation under impact.

Breast Implants: Any subject with breast implants is automatically disqualified from impact acceleration under current HURC policy. Implants are also disqualifying under AFR 160-43 (6-18 (a) 22). The possibility of rupture under impact exists

(especially for saline-filled implants). The long-term effects of impacts on the implant itself or the surrounding capsule (scar tissue) are also not currently known. Thus it is still considered appropriate not to expose such subjects to acceleration.

Mucocele/Polyp/Retention Cyst: A small mass was noted on the routine skull x-rays for this subject. The preliminary diagnosis based solely on the plain film was obviously unclear. An ENT consult was placed, but was not in the subject's medical records. As with many of the above cases, this subject would not have been disqualified by the present panel physicians solely for a nasal polyp. The stringent requirements of a Class I flight physical are often unnecessary, given the specific experimental conditions.

A major factor to consider is the ethical dilemma of allowing a human volunteer with a medical condition, or a history thereof, to participate in more than minimum risk acceleration research. There is some similarity with the case of returning a pilot to flying duty after medical grounding, with the following major differences: 1) the pilot is performing his expected duty, whereas the volunteer is not required to do so; 2) there is an ethical framework defining volunteer treatment (e.g. risk-to-benefit ratio, informed consent); 3) subjects undergo exposure to G stress which is sustained to the point of fatigue, but actual flying is rarely this strenuous; and 4) increased burden on subjects due to monitoring equipment such as rectal and esophageal pressure transducers (42,48,62). A significant common factor is the need for subjects who reflect the population towards whom the acceleration research is directed - the pilots (42,62). This view would tend to support the use of the AF medical standards (AFR 160-43) as one major criterion for disqualification of volunteers for sustained acceleration duty, with a spinal series of x-rays as the other.

Given the nature of the subject pool and current evaluation policy, spinal radiographs fulfill the role of establishing a data base for following the occupational pathology of acceleration exposure by subjects (10). The ethical environment of human-use experimentation notwithstanding, most subjects with a negative medical history become qualified for hazardous duty.

Conclusion

The authors feel that over half (9 of 16) of the medically disqualified subjects over the 1973 to 1993 period would not have been disqualified, as adverse reaction was considered unlikely (e.g., well-controlled diabetic, old history of brief unconsciousness after a blow to the head, presence of a nasal polyp). Those subjects whose disqualification would have been upheld were those who might be expected to suffer injury from the

stresses imposed upon them during experimentation (recurrence of hernia after repair, recurrence of pneumothorax, hematuria if resulting from acceleration).

The previous panel physicians appear to have had a somewhat more conservative degree of clinical judgment. In a larger panel, it is less important to qualify most of the applicants. It should be noted, however, the authors are not suggesting that the health of subjects be compromised in order to facilitate experimentation.

It is also interesting that most subjects are disqualified for mechanical (musculoskeletal) defects rather than for medical problems as we have detailed in the previous chapter. The majority of purely medical problems, such as we have detailed, would not prevent a subject from being intermittently exposed to impacts, or a few minutes of sustained acceleration.

COMPARISON OF ARMSTRONG LABORATORY HUMAN ACCELERATION SUBJECTS TO OTHER SUBJECT AND PILOT POPULATIONS: MUSCULOSKELETAL VARIANT DISTRIBUTION

Introduction

How well do the military human subject acceleration panels represent the spinal status of the pilot population? How well does one subject pool compare with another in terms of spinal variant distribution? The answers to these questions will validate the use of non-pilot volunteer subjects and their particular medical screening criteria.

This chapter compares the two subject populations at Armstrong Laboratory (AL), formerly the Harry G. Armstrong Aeromedical Research Laboratory (AAMRL), with each other and other subject and pilot populations presented in the literature using the parameters of spinal anomalies. The two populations at AL are the Sustained Acceleration Panel (SAP) and the Impact Acceleration Panel (IAP) from 1973 to 1993.

The ultimate concern is the validity of research data generated from the use of human volunteers in the area of impact and sustained acceleration. These data drive cockpit design, helmet configurations, further refinement of the human spine mathematical models, ejection survival strategies, and other protection concepts for aircrew. Lives are at stake (not to mention the large investment in training) as well as billions of dollars in research, development, and acquisition of equipment. The target population is aircrew members consisting of pilots, navigators, weapon system operators, and other specially trained personnel. However, the bulk of the research is directed towards pilots, specifically, those who fly high-performance aircraft. It is not the current policy in the USAF to use fully qualified pilots in basic research, so active duty, non-rated military personnel act as "volunteers". There is, however, a current trend of having several banked pilots on the centrifuge panel due to their availability, perceived need of their expertise, and personal agenda of the pilots. All volunteers must adequately represent the target population in the parameters of interest for valid results. Other countries do not primarily use human subjects because their pilots are screened with x-rays as part of their standard medical exam thereby becoming their own study group (10,38).

Subject Spinal Screening

Over a two year period, Whinnery and Gillingham screened 114 candidates where 81 individuals completed the Flying Class II

physical examination (61). Of 32 disqualified candidates, 8 (25%) were due to spinal anomalies. The only information on spinal lesion distribution comes from the listing of disqualifying anomales (e.g., evidence of degenerative disc disease including Schmorl's nodes; congenital or acquired anomalies of the vertebrae, including transitional vertebrae [although minor degrees of spina bifida occulta may not be disqualifying]). Criteria were based on Kazarian and Belk (31). Thomas et. al. reviewed the qualification of various subject groups in the Navy (56). Subjects were qualified for various types of research (e.g., impact acceleration, ship motion, parachuting effects, and vibration). In all, 1277 prospective volunteers were evaluated with only 63 becoming qualified after passing through the various stages of evaluation. Only 183 had lumbosacral x-rays with the qualifying and disqualifying defects listed in Tables 5 and 6. The disqualification rate of those candidates making the selection process through the volunteer candidate group due to lumbosacral x-rays was 46/183 (25%). The number of candidates with non-disqualifying spinal defects was 71/183 (39%). Some lesions were missed upon initial examination and found later.

Hearon and Raddin did a retrospective study of unsuccessful candidates for Acceleration Stress Duty (ASD) from 1 January 1977 to 31 December 1979 (23). Out of 134 applicants, 71 were disqualified. Of these 71, 45 were medically disqualified, from which 42 were due to radiographic findings.

All of these candidates should have been included in the present study, but there is an obvious discrepancy in the numbers of candidates; 134 candidates for the IAP (1977-1979) compared to 195 candidates in our review from 1973 to 1993. Some of these records may have been misplaced or lost.

Pilot Population Data

Van Dalen and Van Den Biggelaar reported the Netherlands has systematically radiographed the whole spine of both Candidate Student Pilots (CSP) and Qualified Pilots (QP) designated to fly the F-16 since November 1982 (57). Tables 7 and 8 give the distribution of spinal findings from November 1982 to January 1985 for CSP's and QP's.

DeLahaye et. al. have done a large amount of work defining and documenting spinal variants and determining their impact on flying safety and a fliers career (10). Table 9 summarizes their efforts.

TABLE 5: Disqualifying defects and rates of the vertebral spine on 183 individuals undergoing lumbosacral x-rays.

(Thomas et. al. (1977))

DEFECT	NUMBER	PERCENTAGE
Spondylolysis	20	10.9%
Sacralization/Lumbarization	14	7.7%
Excessive Scoliosis	6	3.3%
Vertebral Osteochondrosis	2	1.1%
Cervical Spine	7	
Individuals with disqualifying defects of the spine	46	

Note: Three individuals had two disqualifying defects. No rate is given for cervical spine defects since not all 183 individuals underwent cervical spine x-rays.

TABLE 6: Non-disqualifying lumbosacral spine defects and rates on 183 individuals undergoing lumbosacral spine x-rays. (Thomas et. al. (1977))

DEFECT	NUMBER	PERCENTAGE
Spina Bifida Occulta	31	16.9%
Schmorl's Nodes	11	6.0%
Mild Scoliosis	30	16.4%
Other/Lumbosacral Spine	4	2.2%
Other/Non-lumbosacral Spine	5	
Individuals with Non-disqualifying Vertebral Spine Defects	71	

QUALIFICATION/COMPLETION RATE

qualification rate = 63/1,277 = .049

successfully completing experimental program = 44/1,277 = .034

Note: Eight individuals had two non-disqualifying defects and one had three.

TABLE 7. *Results of Spinal Screening of CSP's* (Van Dalen and Van Den Biggelaar (1985))

N = 225	100%	Number of CSP's examined
45	20%	Rejected for spinal disorders visualized by radiography
22	10%	vertebral osteochondritis (Scheuermann's disease)[1]
13	6%	spondylolysis/lysthesis[2]
5	2%	congenital anomalies[2]
3	1%	discopathies
2	1%	other disorders

[1] Candidates with signs of Scheuermann's disease were rejected when there were more than 2 obvious Schmorl's nodules.

[2] unilateral spondylolysis or a spina bifida occulta with 2 or more vertebrae involved was reason for rejection

TABLE 8. *Results of Spinal Screening of QP's* (Van Dalen and Van Den Biggelaar (1985))

N = 196	100%	number of qualified pilots examined
97	47%	no or very slight disorders
99	51%	one or more disorders, listed below
65	33%	thoracolumbar disorders:
21	11%	Scheuermann's disease: 12 slight
		9 moderate
19	10%	lysis/lysthesis lumbar
12	6%	lumbar discopathy, 1 status post laminectomy
8	4%	congenital anomalies, 6 of these transitional vertebra
3	2%	osteo-arthritis thoraco-lumbar, rather advanced
2	1%	status post moderate compressive fracture T12/L1
48	24%	cervical disorders:
18	9%	cervical discopathy, uncomplicated
16	8%	abnormal alignment, uncomplicated
9	5%	cervical discopathy with osteophytes
5	3%	cervical osteo-arthritis, uncomplicated

70 QP's should have been DQ (36%) with spinal disorders in accord with RNLAF Flight Medical Standard (FMS). 4 pilots rejected from F-16 due to cervical discopathies with osteophyte formation and 3 received G-restriction.

TABLE 9: Incidence of spinal anomalies (DeLahaye et. al. (1982))

1. Scheuermann's Disease (Vertebral Osteochondrosis) based on 2500 military aircrew candidates at CPEMPN, Paris (12.08%) and 2500 military personnel based at HIA Begin, St. Mande (12.75%).
2. Lower thoracic hyperkyphosis (angle > 35°) - 55%.
3. Scoliosis most frequently seen has angle < 20° with 30% being kyphoscoliosis.
    a. thoracolumbar scoliosis 1867/2500 (aircrew) (74.68%) (See Note below)
    b. cervical deviation - 471/2500 (18.84%)
4. End Plate abnormality - 74& slightly irregular end plates
    - 15% grossly irregular end plates
    - 10% regular
5. Spina bifida occulta - 20%
6. Sacralization/Lumbarization - 10%
7. Spondylolisthesis - 3%
8. Anterior wedging of vertebrae 191/2500 (7.64%)
9. Congenital malformations
    a. splitting of posterior arch - 482/2500 (19.82%)
    b. transitional anomalies L5 and S1 - 237/2500 (9.48%)
    c. dissolution of isthmus with spondylolisthesis - 76/2500 (3.04%)
    d. dissolution of isthmus without spondylolisthesis - 38/2500 (1.52%)

Note: This study does not quantitate the measurement of the angles. The table actually lists "disturbance of thoraco-lumbar geometry in frontal plane" as 1867/2500 (74.68%), but breaks this category down into 3 areas as follows:

"Scoliotic posture"	518	(20.72%)
"Scoliosis without pelvic disequilibrium"	839	(34.56%)
"Scoliosis with pelvic disequilibrium"	510	(20.40%)
	Total 2500	(74.68%)

Without a quantitative measurement it is difficult to appreciate clinical significance. It seems overly simplistic to state flatly that three-quarters of aircrew applicants have scoliosis.

Andersen presented the results of the previous four years of radiological examinations on 232 applicants (221 males, 11 females) (3). To reduce the radiation exposure from the 9 films, applicants are only exposed after passing all of the other medical selection criteria. Approximately 10% of the applications go on to radiographical screening. There were 141 lesions in the cervical spine, 173 in the thoracic, and 213 in the lumbar spine (Tables 10 and 11). Anomales were rare in the cervical columan and to some extent in the thoracic spine, but rather frequently seen in the lumbar vertebrae. Degenerative changes occur in the thoracic spine almost twice as frequently as any other portion. Slight to moderate postural changes are evenly distributed among the three subdivisions. The correlation between symptoms and radiographic findings is not definite in spinal disorders. This problem is further compounded when a healthy population of asymptomatic individuals is studied in order to reveal clinical radiographic changes or to predict future functional excellence. Therefore, the radiological evidence must be interpreted with great caution.

Hirsch and Nachemson performed radiological examinations on 55 pilots who had ejected (27). In the course of their evaluation additional findings were discovered (Table 12).

"Normal" Population

The following data was retrieved from the literature to present representative values of spinal variant distributions from other pilot or subject populations for comparison. Distribution of disc degenerative changes determined from epidemiologic radiographic surveys indicate the prevalence in an urban population to be 35% (Grade 2) at the cervical spine for females and 30% (Grade 2) for males. Grade 3-4 changes are 30% female and 44% male. The lumbar spine was 15% (Grade 3-4) and 34% (Grade 2) for female. For males it was 25% (Grade 3-4) and 42% (Grade 2) (32).

Kostuik and Bentivoglio found a prevalence of 3.9% for curves involving the adult thoracolumbar and lumbar spine in a review of 5000 intravenous pyelograms (33). Dewar (unpublished data reported in Shands and Eisberg [52]) analyzed 10,000 consecutive chest x-rays for routine hospital admission and found a prevalence rate of 4% for true structural curves. It must be noted, however, that the actual angle measurement of these curves was not recorded. Therefore, it is unclear if there is any physiologic significance. However, Shands and Eisberg studied a representative sample of 194,060 chest x-rays in the state of Delaware in 1953 (82.2% of the population over 14) (52):

a. 1.4% had mild curves (10-19 degrees)
b. 0.3% had moderate curves (20-29 degrees)
c. 0.2% had significant curves (> 30 degrees)

TABLE 10: *Roentgen Changes* (Andersen (1989))

Anomalies	
Cervical fused vertebrae	2
Thoraco-lumbar transitional vertebrae	21
Lumbo-sacral transitional vertebrae	20
Extra vertebrae	8
Spina bifida	49
Total	100
Aberrations of posture	
Scoliosis	95
Curvatures straightened out	89
Hyperkyphosis/-lordosis	35
Total	219
Degenerative changes	
Spondylolysis/-olisthesis (5+7)	12
Seq MB Scheuermann	36
Schmorl's Nodes	34
Loss of disc height	41
Osteochondrosis	9
Trapezoid vertebrae	16
Previous injury	10
Operated	2
Total	160
SUM TOTALS	479

TABLE 11: *Radiological Examination Consequences* (Andersen (1989))

Applicants, total number	232
Negative films - "Normal"	76
Acceptable radiology	131
Excluded by radiology only	20
Excluded, radiology contributing	5

Table 12: Additional Radiological Findings from 55 Ejected Pilots (Hirsch and Nachemson (1961))

Spondylolisthesis.....	3 cases
(in all cases involving L5)	
Vertebral osteochondritis.....	4 cases
Schmorl's nodules.....	4 cases
old Vertebral fracture.....	1 case
disk degeneration.....	1 case
Hemangioma.....	1 case

In all, 1.9% of population had a spinal curvature, with a fairly consistent age distribution. (Compare to the approximately 4% reported in the previously mentioned studies).

They also reported that data from Niebauer (personal communication) was similar, where prevalence was 2.5/100, but in the age group of 20-65 years this rose to 4.2/100.

As discussed in chapter 2, Andersson stated that the prevalence of disc degeneration is associated with increasing age beginning in the third decade, varies with gender depending on the study performed, is most seen at L-4 and L-5 levels in the throacolumbar spine and C-5 in the cervical spine, and is difficult to detect using x-rays until quite severe (4).

Epstein presented varying data on spinal lesion distribution (13). Spina bifida occulta (SBO) occurred in 18.2% of 550 patients (2.2% in limbar spine and 16% sacrum) of whom most had little or no symptoms (53). Dittrich found SBO in 5% of all spine radiographical exams (11). Breck et. al. found SBO in 6% of 450 cases (6). Freidman et. al. found it in 36 out of 100 soldiers (15). Schmorl and Junghanns found a 38% incidence of Schmorl's Nodes anatomically (only 13.5% radiographically) (51). For spondylolisthesis, Bailey found 5% (5).

AL Subject Panel Data

The following data was compiled from the research medical records of active, disqualified, and terminated subjects at Armstrong Laboratory from 1973 to 1993. These subjects were all active duty military except for two government civilians. All were asymptomatic except: 1) an individual with a chronic shoulder problem, who was cleared for select programs and was eventually terminated due to shoulder problems; and 2) an individual with a history of low back pain who did not bring this forward during the initial history gathering session and was later disqualified in the qualification process when the history was discovered. By no means is the panel representative of the Air Force population: 1) the impact panel has a higher proportion of enlisted personnel than the centrifuge; 2) people usually hear about the panel from a member of the panel, so there tends to be groups of individuals who work together in their full time job; and 3) panel members tend to have special job skills because of the emphasis on research, acquisition, and education at Wright-Patterson Air Force Base (see Tables 13 and 14).

TABLE 13: Human Subject Musculoskeletal Data - 1973-1993 from Armstrong Laboratory

	Centrifuge (123)[1]	Impact (161)[1]	Combined (284)[1]
kyphosis	1 (0.8%)	0 (0%)	1(0.4%)
degenerative changes	20 (16.2%)	18 (11.2%)	38 (13.4%)
Spondylosis	2 (1.6%)	0 (0%)	2 (0.7%)
Spondylolysis	2 (1.6%)	4 (2.5%)	6 (2.1%)
Schmorl's Nodes	13 (10.6%)	8 (5%)	21 (7.4%)
Negative findings	61 (49.6%)	92 (57%)	153 (54%)
Fusion anomalies:			
pars defects	3 (2.4%)	5 (3%)	8 (2.8%)
spina bifida occulta	3 (2.4%)	9 (5.6%)	12 (4.2)
fusion defects	1 (0.8%)	2 (1.2%)	3 (1.0%)
lumbarsacralization	1 (0.8%)	0 (0%)	1 (0.35%)
sacralization	2 (1.6%)	0 (0%)	2 (0.7%)

[1] Numbers of subjects having at least one set of x-rays available for evaluation

TABLE 14: HUMAN SUBJECT SCOLIOSIS DATA - 1973 TO 1993 FROM ARMSTRONG LABORATORY

(a) Data from Centrifuge (123 candidates with x-rays)

Type of Scoliosis	$\leq 10°$	$10° < \leq 25°$	$> 25°$
Cervical	2 (1.6%)	0	0
Cervicothoraco	0	0	0
Thoracic	31 (25%)	3 (2.44%)	0
Thoracolumbar	4 (3.3%)	1 (0.8%)	0
Lumbar	14 (11.4%)	3 (2.44%)	0

(b) Data from Impact Panel (161 candidates with x-rays)

Type of Scoliosis	$\leq 10°$	$10° < \leq 25°$	$> 25°$
Cervical	0	0	0
Cervicothoraco	1 (0.6%)	0	0
Thoracic	24 (15%)	2 (1.2%)	0
Thoracolumbar	9 (5.6%)	0	0
Lumbar	20 (12.4%)	3 (1.9%)	0

(c) Combined Data of Panels (284 candidates with x-rays)

Type of Scoliosis	$\leq 10°$	$10° < \leq 25°$	$> 25°$
Cervical	2 (0.7%)	0	0
Cervicothoraco	1 (0.4%)	0	0
Thoraco	55 (19.4%)	5 (1.76%)	0
Thoracolumbar	13 (4.6%)	1 (0.4%)	0
Lumbar	34 (12%)	6 (2.11%)	0

US Pilot Population (Clinical Sciences Division Database)

The group to which the subject panels should be compared, the US pilot population, does not have a readily accessible, useable or representable database. Currently, there are two possible sources. One, maintained by the Research Coordination Branch (Clinical Sciences Division, Brooks AFB), follows the medical course of the individual over time. The other source is the listing of current waivered pilots. The advantage of the first database (see Table 15) is historically a chest x-ray and KUB were standard in the evaluation process. This provided a better measure of prevalence of spinal anomalies than the typical waiver workup. Data is coded using The International Classification of Diseases Clinical Modification (ICD•9•CM). Problems with this classification for military aerospace medicine use is the lack of location and quantification for scoliosis. These considerations are critical if any epidemiological studies with subsequent correlations of injury to condition are to be attempted. Even with the word descriptions, a problem of standardization is apparent. Mild, moderate, and prominent were used to describe the degree of scoliosis. However, consistency among follow-ups was lacking due to differences between raters. For the purposes of this study mild was assumed to be $\leq 10°$, moderate $10° \leq \leq 25°$, and prominent $\geq 25°$. This provided the same categories as the subject panels. However, the margin for error is potentially large due to inconsistencies in verbal description matching magnitude of scoliosis. Thus, additional analysis was performed combining all magnitudes of scoliosis into their respective thoracic, lumbar and thoracolumbar classifications for comparison.

Discussion

There are several difficulties in comparing the different sources of spinal lesion distribution: 1) lack of a good description of the sample population (e.g., whether asymptomatic or symptomatic); 2) inconsistencies in reading the radiographical data (i.e., initial subject panel x-rays were read as negative, yet termination x-rays noted a scoliosis that had not changed from initial); 3) terminology (e.g., mild or slight scoliosis instead of degrees); 4) categorization (i.e., combining groups together in one study that were separated in another); and 5) failure to specify the particular lesions. These reasons dictated the presentation of the data from other studies in separate tables as presented by the authors themselves to emphasize this problem.

One can question whether it is meaningful to compare the different populations as attempted. For example, in the detection of spina bifida occulta, prevalences of 5%, 6%, 18.2%, and 36% were reported in the literature. We would be inclined to ascribe this degree of variability to measurement techniques

rather than to actual anatomical differences. However, these discrepancies must be addressed if any changes are to be made for future studies.

Results

The hypotheses tested were the differences between two population proportions using an estimated proportion of the populations in question, a weighted average of p and q, samples from the two populations being tested (n_1, n_2), and an estimate of the standard deviation. The level of significance is $\alpha = .05$. Therefore $Z_{\alpha/2} = \pm 1.96$ represents the value which the sample statistic (if outside the boundaries) will render the hypothesis H_o untenable. The following equations defines the Null hypothesis and parameters used in determining the value of Z:

$$H_0: p_1 - p_2 = 0$$

$$Z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\hat{p}_w \hat{q}_w \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

$$where\ \hat{p}_w = \frac{n_1 \hat{P}_1 + n_2 \hat{P}_2}{n_1 + n_2},$$

$$\hat{q}_w = \frac{n_1 \hat{q}_1 + n_2 \hat{q}_2}{n_1 + n_2}, and$$

$$s_{\hat{p}_1 - \hat{p}_2} = \sqrt{\hat{p}_w \hat{q}_w \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

There is a large margin for error just in the reading of the radiographs alone given the disparities between initial and termination radiographic interpretation for the AL panels (radiographs were read by Radiology Department at the Medical Center, WPAFB, with occasional consultation with the Orthopedic Department). With 54% of the candidates reported as negative, this leaves a significant source of possible undetected anomalies.

TABLE 15: US Pilot Spinal Anomaly Distribution (Brooks AFB)

(n=2484)

Kyphosis 22 (.89%)
spondylolysis 3 (0.1%)
pars defects 1 (0.04%)
spondylolisthesis 19 (1%)
sacralization 6 (0.2%)
Scheuermans Dz 1 (0.04%)
HNP 85 (3%)
kyphoscoliosis 28 (1.1%)
osteoarthritis 14 (.56)
spondylosis 17 (1%)
ankylosing spondylitis 4 (.16%)
Degenerative changes 1325 (53%)
Schmorl's Nodes 10 (0.4%)
Spina Bifida 595 (24%)
lumbarization 1 (0.04%)
scoliosis (unk) 33 (1%)
osteoporosis 4 ((.16%)
fusion 2 (0.8%)
compression fracture 12 (.48%)
lordosis 55 (2%)
osteopenia 4 (.16%)

Scoliosis Distribution (n=2484)

	$\leq 10°$	$10° < \leq 25°$	$\geq 25°$
cervical spine	4 (.16%)	1 (.04%)	0
cervicothoracic	2 (.08%)	0	0
thoracic spine	665 (27%)	54 (2.17%)	2 (.08%)
thoracolumbar	135 (5.43%)	26 (1.05%)	2 (.08%)
lumbar spine	137 (5.52%)	9 (.36%)	0

The statistical comparison between the various groups of subjects, pilots and the normal population is presented in Table 16.

In comparing the AL panels, only the proportion of pars defects, fusion defects, and lumbar scoliosis ($\leq 10°$, $10° < \leq 25°$) are considered the same. The Navy subject experience (see Table 16, Thomas (56) vs AL Panels) has only the proportion of Schmorl's nodes and lumbar scoliosis the same as both AL panels (56). The French pilot/candidate database (DeLahaye et. al. vs AL panels) is only similar in regards to degenerative changes with the AL impact panel (10). The Norwegian study (Andersen 1989 vs AL panels) had scoliosis and fusion defects rates in common with both AL panels with the addition of Schmorl's nodes for the centrifuge panel and the disqualification rate for the impact panel (3). The post-ejection study of Hirsch and Nachemson had the incidence of Schmorl's nodes in common with both AL panels (27). The data from Van Dalen and Van Den Biggelaar (57) indicated that the disqualification rate for current pilots (based on practical considerations) was the same as the AL centrifuge panel disqualification rate.

For the US pilot database, the proportion of spondylosis, kyphosis, lumbosacralization, sacralization, cervical scoliosis ($\leq 10°$), cervicothoracic scoliosis ($\leq 10°$), thoracic scoliosis ($10° < \leq 25°$, $> 25°$), and thoracolumbar scoliosis ($\leq 10°$, $10° < \leq 25°$, $> 25°$) were the same as the Impact panel. Spondylosis, kyphosis, cervicothoracic scoliosis ($\leq 10°$), thoracic scoliosis ($\leq 10°$, $10° < \leq 25°$, $> 25°$), and thoracolumbar scoliosis ($\leq 10°$, $10° < \leq 25°$, $> 25°$) proportions were the same as the Centrifuge panel. Combining the magnitudes within categories yielded similar proportions between thoracolumbar scoliosis (impact) and thoracic and thoracolumbar scoliosis (centrifuge). It is encouraging to see that the panels are more similar to the US pilot database than any other source; although, this sample does not represent the overall pilot pool.

TABLE 16: Statistical Analysis of Subject and Pilot Spinal Lesion Distribution

(a) CENTRIFUGE [n1] VS IMPACT [n2]

CATEGORY	p1	n1	p2	n2	pw	qw	Z	p-value
kyphosis	0.008	123	0	161	0.0035	0.9965	3.1080	.001
degen chg	0.162	123	0.112	161	0.1337	0.8663	3.3543	.001
spondylosis	0.016	123	0	161	0.0069	0.9931	4.4030	.001
spondylolysis	0.16	123	0.025	161	0.0835	0.9165	11.1423	.001
schmorls Node	0.106	123	0.05	161	0.0743	0.9257	4.8759	.001
neg findings	0.496	123	0.57	161	0.5380	0.4620	-3.3884	.001
pars defect	0.024	123	0.03	161	0.0274	0.9726	-0.8390	**.20**
spina bifida	0.024	123	0.056	161	0.0421	0.9579	-3.6360	.001
fusion	0.008	123	0.012	161	0.0103	0.9897	-0.9058	**.18**
lumbosacral	0.008	123	0	161	0.0035	0.9965	3.1080	.001
sacralization	0.016	123	0	161	0.0069	0.9931	4.4030	.001
CS1[1]	0.016	123	0	161	0.0069	0.9931	4.4030	.001
TS1[2]	0.25	123	0.15	161	0.1933	0.8067	5.7809	.001
TS2[3]	0.024	123	0.012	161	0.0172	0.9828	2.1071	.018
LS1[4]	0.114	123	0.124	161	0.1197	0.8803	-0.7033	**0.24**
LS2[5]	0.024	123	0.019	161	0.0212	0.9788	0.7930	**0.21**
TLS1[6]	0.033	123	0.056	161	0.0460	0.9540	-2.5054	.006
TLS2[7]	0.008	123	0	161	0.0035	0.9965	3.1080	.001
DQ rate	0.016	123	0.11	161	0.0693	0.9307	-8.4501	.001

Note:

[1]CS1 - cervical spine scoliosis less than or equal to 10°

[2]TS1 - thoracic spine scoliosis less than or equal to 10°

[3]TS2 - thoracic spine scoliosis 10°< ≤ 25°

[4]LS1 - lumbar spine scoliosis less than or equal to 10°

[5]LS2 - lumbar spine scoliosis 10°< ≤ 25°

[6]TLS1 - thoracolumbar spine scoliosis less than or equal to 10°

[7]TLS2 - thoracolumbar spine scoliosis between 10°< ≤ 25°

TABLE 16: Statistical Analysis of Subject and Pilot Spinal Lesion Distribution (cont)

(b) Comparison of Thomas, et. al.,(1977)[n1] with AL panels [n2]

CENTRIFUGE[n2]

CATEGORY	p1	n1	p2	n2	pw	qw	Z	p-value
spondylosis	0.109	183	0.016	123	0.0716	0.9284	3.0933	.001
Schmorls Node	0.06	183	0.106	123	0.0785	0.9215	-1.4670	**.07**
spina bifida	0.169	183	0.024	123	0.1107	0.8893	3.9633	.001
lumbosacral	0.077	183	0.024	123	0.0557	0.9443	1.9821	.001
L Scoliosis	0.20	183	0.14	123	0.1759	0.8241	1.3516	**.088**
DQ rate	0.25	183	0.016	123	0.1159	0.8441	5.5318	.001

IMPACT[n2]

CATEGORY	p1	n1	p2	n2	pw	qw	Z	p-value
spondylosis	0.109	183	0	161	0.0580	0.9420	4.3162	.001
Schmorls Node	0.06	183	0.05	161	0.0553	0.9447	0.4048	**.34**
spina bifida	0.169	183	0.056	161	0.1161	0.8839	3.2644	.001
lumbosacral	0.077	183	0	161	0.0410	0.9590	3.5953	.001
L Scoliosis	0.20	183	0.14	161	0.1719	0.8281	1.4717	**.071**
DQ rate	0.25	183	0.11	161	0.1845	0.8155	3.3404	.001

(c) Comparison of DeLahaye et. al.,(1982)[n1] with AL panels [n2]

CENTRIFUGE[n2]

CATEGORY	p1	n1	p2	n2	pw	qw	Z	p-value
deg chg	0.0764	2500	0.162	123	0.0804	0.9196	-3.4083	.001
spina bifida	0.2	2500	0.024	123	0.1917	0.8083	4.8406	.001
lumbosacral	0.1	2500	0.024	123	0.0964	0.9036	2.7876	.003

IMPACT[n2]

CATEGORY	p1	n1	p2	n2	pw	qw	Z	p-value
deg chg	0.0764	2500	0.112	161	0.0786	0.9214	-1.6274	**.05**
spina bifida	0.2	2500	0.056	161	0.1913	0.8087	4.5028	.001
lumbosacral	0.1	2500	0	161	0.0939	0.9061	4.2154	.001

TABLE 16: Statistical Analysis of Subject and Pilot Spinal Lesion Distribution (cont)

(d) Comparison of Andersen (1989)[n1] with AL panels [n2]

CENTRIFUGE[n2]

CATEGORY	p1	n1	p2	n2	pw	qw	Z	p-value
Schmorls Node	0.15	232	0.106	123	0.1348	0.8652	1.1553	**.13**
spondylolysis	0.02	232	0.16	123	0.0685	0.9315	-4.9688	.001
spina bifida	0.21	232	0.024	123	0.1456	0.8544	4.7287	.001
fusion	0.009	232	0.008	123	0.0087	0.9913	0.0968	**.46**
lumbarsacral	0.09	232	0.008	123	0.0616	0.9384	3.0581	.001
CS	0.41	232	0.47	123	0.4308	0.5692	-1.0863	**.46**
neg	0.33	232	0.496	123	0.3875	0.6125	-3.0549	.001
DQ rate	0.11	232	0.016	123	0.0774	0.9226	3.1532	.001

IMPACT[n2]

CATEGORY	p1	n1	p2	n2	pw	qw	Z	p-value
Schmorls Node	0.15	232	0.05	161	0.1090	0.8910	3.1279	.001
spondylolysis	0.02	232	0.025	161	0.0220	0.9780	-0.3320	**.37**
spina bifida	0.21	232	0.056	161	0.1469	0.8531	4.2409	.001
fusion	0.009	232	0.012	161	0.0102	0.9898	-0.2907	**.39**
lumbarsacral	0.09	232	0	161	0.0531	0.9469	3.9119	.001
Scoliosis	0.41	232	0.37	161	0.3936	0.6064	0.7982	**.21**
neg finding	0.33	232	0.57	161	0.4283	0.5717	-4.7284	.001
DQ rate	0.11	232	0.11	161	0.1100	0.8900	0.0000	**.5**

(e) Hirsch and Nachemson (1961)[n1] vs AL panels[n2]

CENTRIFUGE [n2]

CATEGORY	p1	n1	p2	n2	pw	qw	z	p-value
spondylolysis	0.05	55	0.16	123	0.1260	0.8740	-2.0434	.021
Schmorls Node	0.07	55	0.106	123	0.0949	0.9051	-0.7573	**.22**
deg disease	0.02	55	0.162	123	0.1181	0.8819	-2.7123	.003

IMPACT [n2]

CATEGORY	p1	n1	p2	n2	pw	qw	z	p-value
spondylolysis	0.05	55	0.025	161	0.0314	0.9686	0.9183	**.18**
Schmorls Node	0.07	55	0.05	161	0.0551	0.9449	0.5612	**.29**
deg disease	0.02	55	0.112	161	0.0886	0.9114	-2.0732	.02

TABLE 16: Statistical Analysis of Subject and Pilot Spinal Lesion Distribution (cont)

(f) Van Dalen and Van Den Biggelaar (1985) [n1] vs AL panels [n2]

CENTRIFUGE [n2]

CATEGORY	p1	n1	p2	n2	pw	qw	z	p-value
DQ rate CSP	0.2	225	0.016	123	0.1350	0.8650	4.8022	.001
DQ rate QP[1]	0.36	196	0.016	123	0.2274	0.7726	7.1351	.001
DQ rate QP[2]	0.02	196	0.016	123	0.0185	0.9815	0.2583	.4

IMPACT [n2]

CATEGORY	p1	n1	p2	n2	pw	qw	z	p-value
DQ rate CSP	0.2	225	0.11	161	0.1625	0.8375	2.3636	.009
DQ rate QP[1]	0.36	196	0.11	161	0.2473	0.7527	5.4482	.001
DQ rate QP[2]	0.02	196	0.11	161	0.0606	0.9394	-3.5467	.001

(g) Normal Population[n1] vs AL panels[n2]

CENTRIFUGE [n2]

CATEGORY	p1	n1	p2	n2	pw	qw	z	p-value
Thoracic and lumbar scoliosis[3]	0.04	10000	0.18	123	0.0417	0.9583	-7.7197	.001
Thoracic and lumbar scoliosis[3]	0.017	194060	0.18	123	0.0171	0.9829	-13.9383	.001
Spina bifida occulta[4]	0.182	550	0.024	123	0.1531	0.8469	4.3990	.001
Spina bifida occulta[4]	0.062	450	0.024	123	0.0538	0.9462	1.6547	.049

TABLE 16: Statistical Analysis of Subject and Pilot Spinal Lesion Distribution (cont)

IMPACT [n2]

CATEGORY	p1	n1	p2	n2	pw	qw	z	p-value
Thoracic and lumbar scoliosis[3]	0.04	10000	0.2	161	0.0425	0.9575	-9.9800	.001
Thoracic and lumbar scoliosis[3]	0.017	194060	0.2	161	0.0172	0.9828	-17.8767	.001
Spina bifida occulta[4]	0.182	550	0.056	161	0.1535	0.8465	3.9012	.001
Spina bifida occulta[4]	0.062	450	0.056	161	0.0604	0.9396	0.2742	**.39**

(h) Whinnery and Gillingham (1983)[n1] vs AL panels [n2]

CENTRIFUGE [n2=123], IMPACT [n2=161]

CATEGORY	p1	n1	p2	n2	pw	qw	z	p-value
DQ rate	0.1	81	0.016	123[5]	0.0494	0.9506	2.7101	.003
DQ rate	0.1	81	0.11	161[6]	0.1067	0.8933	-0.2378	**.41**

(i) Candidate Screening Data,n1 (centrifuge), n2 (impact)

Category	p1	n1	p2	n2	pw	qw	z	p-value
DQ	0.05	132	0.18	195	0.1275	0.8725	-3.4578	.001
Q	0.95	132	0.82	195	0.8725	0.1275	3.4578	.001
% Spinal	0.29	7	0.71	34	0.6383	0.3617	-2.1060	.018

Note:

[1] Pilots that <u>should</u> have been disqualified based on RNLAF FMS

[2]Pilots disqualified based on cervical discopathy with osteophtes

[3,4]Two sets of data from normal population with different proportions

[5]Number of subjects from AL Centrifuge panel

[6]Number of subjects from AL Impact panel

Table 16: Statistical Analysis of Subject and Pilot Spinal Lesion Distribution (cont)

(j) US Pilot Database (Brooks AFB)[n1] vs AL Panels [n2]

			Impact [n2]					
Category	p1	n1	p2	n2	pw	qw	z	p-value
spondylosis	0.01	2484	0	161	0.0094	0.9906	1.2749	**0.10**
degen. changes	0.53	2484	0.112	161	0.5046	0.4954	10.2802	0.001
Schmorls Nodes	0.004	2484	0.05	161	0.0068	0.9932	-6.8827	0.001
kyphosis	0.01	2484	0	161	0.0094	0.9906	1.2749	**0.10**
spondylolysis	0.001	2484	0.025	161	0.0025	0.9975	-5.9563	0.001
pars defects	0.0004	2484	0.03	161	0.0022	0.9978	-7.7654	0.001
SBO	0.24	2484	0.056	161	0.2288	0.7712	5.3862	0.001
fusion	0.0008	2484	0.012	161	0.0015	0.9985	-3.5804	0.001
lumbosacralization	0.0004	2484	0	161	0.0004	0.9996	0.2538	**0.40**
sacralization	0.0024	2484	0	161	0.0023	0.9977	0.6223	**0.27**
CS1[1]	0.0016	2484	0	161	0.0015	0.9985	0.5079	**0.31**
CT1[2]	0.0008	2484	0.006	161	0.0011	0.9989	-1.9146	0.028
TS1[3]	0.27	2484	0.15	161	0.2627	0.7373	3.3528	0.001
TS2[4]	0.02	2484	0.012	161	0.0195	0.9805	0.7112	**0.24**
TS3[5]	0.0008	2484	0	161	0.0008	0.9992	0.359	**0.359**
Thoracic Scol.[4]	0.29	2484	0.16	161	0.2821	0.7179	3.5522	0.001
LS1[7]	0.06	2484	0.124	161	0.0639	0.9361	-3.2178	0.001
LS2[8]	0.0036	2484	0.019	161	0.0045	0.9955	-2.8176	0.002
Lumbar Scoliosis[9]	0.06	2484	0.14	161	0.0649	0.9351	-3.9940	0.001
TLS1[10]	0.05	2484	0.056	161	0.0504	0.9496	-0.3374	**0.37**
TLS2[11]	0.01	2484	0	161	0.0094	0.9906	1.2749	**0.10**
TLS3[12]	0.0008	2484	0	161	0.0008	0.9992	0.6785	**0.248**
Thoracolumbar[10]	0.07	2484	0.056	161	0.0691	0.9309	0.6785	**0.248**

TABLE 16: Statistical Analysis of Subject and Pilot Spinal Lesion Distribution (cont)

			Centrifuge [n2]					
Category	p1	n1	p2	n2	pw	qw	z	p-value
spondylosis	0.01	2484	0.016	123	0.0103	0.9897	-0.6439	**0.26**
degen. changes	0.53	2484	0.162	123	0.5126	0.4874	7.9703	0.001
Schmorls Nodes	0.004	2484	0.05	123	0.0062	0.9938	-6.3593	0.001
kyphosis	0.01	2484	0.008	123	0.0099	0.9901	0.2186	**0.42**
spondylolysis	0.001	2484	0.16	123	0.0085	0.9915	-18.7480	0.001
pars defects	0.0004	2484	0.024	123	0.0015	0.9985	-6.5722	0.001
SBO	0.24	2484	0.024	123	0.2298	0.7702	5.5581	0.001
fusion	0.0008	2484	0.008	123	0.0011	0.9989	-2.3102	0.01
lumbosacralization	0.0004	2484	0.008	123	0.0008	0.9992	-2.9884	0.001
sacralization	0.0024	2484	0.016	123	0.0030	0.9970	-2.6736	0.004
CS1[1]	0.0016	2484	0.016	123	0.0023	0.9977	-3.2689	0.001
CTS1[2]	0.0008	2484	0	123	0.0008	0.9992	0.3138	**0.378**
TS1[3]	0.27	2484	0.25	123	0.2691	0.7309	0.4882	**0.31**
TS2[4]	0.02	2484	0.024	123	0.0202	0.9798	-0.3079	**0.38**
TS3[5]	0.0008	2484	0	123	0.0008	0.9992	0.3138	**0.378**
Thoracic Scol.[6]	0.29	2484	0.28	123	0.2895	0.7105	0.2387	**0.405**
LS1[7]	0.06	2484	0.114	123	0.0625	0.9375	-2.4142	0.008
LS2[8]	0.0036	2484	0.024	123	0.0046	0.9954	-3.2770	0.001
Lumbar Scoliosis[9]	0.06	2484	0.14	123	0.0638	0.9362	-3.5443	0.001
TLS1[10]	0.05	2484	0.033	123	0.0492	0.9508	0.8509	**0.20**
TLS2[11]	0.01	2484	0.008	123	0.0099	0.9901	0.2186	**0.41**
TLS3[12]	0.0008	2484	0	123	0.0008	0.9992	0.3138	**0.378**
Thoracolumbar scol[13]	0.07	2484	0.04	123	0.0686	0.9314	1.2850	**0.10**

Note:

[1]CS1 - cervical spine scoliosis less than or equal to 10°

[2]CT1 - cervicothoracic scoliosis less than or equal to 10°

[3]TS1 - thoracic spine scoliosis less than or equal to 10°

[4]TS2 - thoracic spine scoliosis ($10° < \leq 25°$)

[5]TS3 - thoracic spine scoliosis > 25°

[6]Thoracic Scol - combination of all magnitudes of thoracic scolioses

[7]LS1 - lumbar spine scoliosis less than or equal to 10°

[8]LS2 - lumbar spine scoliosis ($10° < \leq 25°$)

[9]Lumbar Scoliosis - combination of all magnitudes of lumbar scolioses

[10]TLS1 - thoracolumbar spine scoliosis less than or equal to 10°

[11]TLS2 - thoracolumbar spine scoliosis ($10° < \leq 25°$)

[12]TLS3 - thoracolumbar spine scoliosis greater than 25°

[13]Thoracolumbar scol - combination of all magnitudes of thoracolumbar scolioses

WHICH DIRECTION FOR USAF SUBJECT PANELS?

Introduction

The United States (US) is unique throughout the world in the expanded role of human volunteers, who are not pilots, in acceleration research. Part of this is due to the size of its military and the budget committed to acceleration research. However, in today's world economy, this may now be a luxury.

One of the major differences between the US and other foreign Air Forces is the US's lack of spinal radiographic screening (10,38). The rationale in the past has been excessive exposure to radiation and the absence of a significant bearing on the flying future of the candidates (10). Another reason, not readily apparent, is the dominance of the pilot in the command structure. This arrangement ensures policies are enacted that do not jeopardize a pilot's flying status (e.g., pilots not monitored by ECG in the centrifuge so as to not have to explain abnormal findings). There are valid reasons for the paranoia regarding excessive screening and monitoring during flight. It required a policy letter from the Air Force Surgeon General to eliminate the full-scale workup of a pilot for "loss of consciousness" during centrifugation if the episode followed the expected pattern (MG Chesney, AF/SG Policy on LOC, 25 April 1983).

Several articles have addressed the issue of changing the way US pilots are screened: 1) adding A/P and lateral spinal x-rays, blood lipids, and maximal exercise stress testing for selection followed by periodic repeated lipids, maximal exercise stress testing, spinal x-rays with added "State of the Art" tests (e.g., echocardiography) as other clinical entities become more commonly diagnosed such as Mitral Valve Prolapse; factoring age into decisions for training and aircraft assignment; modifying waiver policies to restrict waivers to conditions not influenced by high sustained G loading; and changing the "Fly one, Fly all" concept as not all "apparently healthy" aviators are capable of flying high performance aircraft due to relatively poor G tolerance or the presence of relatively mild medical conditions that have the potential for sudden incapacitation under high G loading (24); 2) later, Hickman took a different tact regarding cardiovascular standards in the "dual track" training system in recommending echocardiograms in selecting Fighter-Attack-Reconnaissance pilots after the normal screening for initial pilot training while dropping the exercise stress test (25); and 3) DeHart (9) presented data that the current examination procedures missed about 3.7% of conditions that resulted in pilot incapacitation or premature attrition due to repeated exposure to high-G. An echocardiogram and spine series would detect most of these conditions.

The problems associated with having different screening criteria for pilots and subjects have been addressed in Chapter 1. It could be argued that as experimental limits of acceleration exposure expand to meet the demand of increasing aircraft performance, data from radiographically scrubbed subjects may give a false sense of security regarding the effects of pilots who have not been as thoroughly screened.

Discussion

There are several options available for the US: 1) match the screening criteria for pilots and subjects, at least the most germane (e.g., spinal). There is also a potential concern over possible psychological/personality differences that may impact experimental performance metrics (37); 2) eliminate human subject panels and use primarily pilots themselves; or 3) contiue the current policy.

Option 1 would better assure that subjects represent the pilots for proper interpretation of experimental data. It would also allow for the development of a comprehensive data base, similar to that of the French, on the occupational hazards of flying (10). An unexplored area is the effect of personality on the various performance metrics used in sustained acceleration research. There is a large amount of anecdotal evidence indicating pilots are unique, although documenting it has proved elusive. Many of the personality tests have low r values and some are inappropriately used. Several studies utilized the Edwards Personality Preference Schedule (EPPS) to measure the personality attributes of different segments of the pilot population (18,35,39,40,44,45,46). A detailed review of the literature revealed an inherent flaw by using data generated from the EPPS to make statements on group normative values and comparisons between groups using standard statistical tools. This is due to the ipsative design of the EPPS. The error in using the EPPS for group statistics has been presented in the literature off and on for over 20 years, but studies are still being done using it inappropriately (8,26,29,43,49,50).

Option 2 would generate some interesting decisions regarding the degree of screening. Would the pilots be regarded as "subjects" and be treated in light of current human use ethical standards (e.g., risk-to-benefit ratio, extensive medical screening including radiographic examination) or would this be just another "assignment"? Using existing USAF medical screening criteria, Chapter 5 compared subject panels to various pilot groups and normal populations. Medical probelms (e.g., diabetes, hematuria) or musculoskeletal problems that were aggravated by acceleration exposure constituted an overwhelming majority of disqualified candidates for the panels. It would seem prudent to gather data on the spinal variant distribution in pilots and correlate this with the hazards of flying (e.g., ejection, high-G exposure, long

duration vibration). This process would be invaluable in modifying existing screening criteria to protect pilots as technology pushes the operating envelope to further limits.

Option 3 maintains the status quo. In these rapidly changing times of budgetary constraints and reorganization, this may seem to be the best course. However, point five of the Deming Management Method stresses constant improvement of the system (59). By doing nothing, valuable data will be lost that could be used to protect the pilot population.

Conclusions

There are major changes in the way business is being done on a world-wide scale. Government and military technologies are being pushed to rapidly integrate with civilian industry. Given this scenario, it is probably an opportune time to reevaluate the way human-use aeromedical research is conducted. Goals must be established with appropriate objectives that will mesh with the new world order: joint ventures with foreign air forces; a common standard for medical screening to facilitate comparisons; and validity of using non-pilots vs pilots in research. These efforts will not be easy as there are differences even between the US military services in their use of human subjects.

Recommendations

With the many difficulties in comparing data from study to study and country to country, a standardized format and description of anomalies would greatly facilitate comparisons and combining databases. The French (10) have a good start on documenting spinal anomalies, including descriptions of the methodologies utilized and the anomalies.

A greater problem is the interrater variability. This may be minimized by using the type of system established by the International Labor Office (ILO) for certain occupational lung diseases. Physicians can be certified to read radiographs based on their qualifications (A-, B-, and C-readers). One highly desirable aspect is the provision of a standard series of graded x-rays against which the degree of abnormality present is judged.

Given these sources of error, it is not too difficult to see why the subject panel populations are not very similar either to themselves or other population groups.

The US military pilot community should be radiographically evaluated, but <u>not screened</u>. This would establish a database from which to make informed decisions in the future as well as provide the means to track the occupational pathology of flying. If the existing medical history and screening do not pick up

critical spinal pathology and epidemiological data do not indicate a problem with pilots being grounded for spinal problems, then anything found on radiographic evaluation should just be filed for future reference. This database could then be used to make intelligent decisions on the significance of the various anomalies. This is critical as the performance of aircraft continues to improve which makes the ejection seat envelope more hazardous (one of the goals of human impact acceleration research is to make the safe ejection envelope coincident with the flight envelope of the aircraft. This approach was advocated by Jones (30) in his examination of the derivation of physical standards. A major difficulty to overcome is the perception of the pilot that a promise by the Air Force to make non-screening spinal x-rays "nonretributional" would not be kept. There is historical evidence to support this perception (e.g., the bicycle ergometry program that replaced the mile and a half run was supposed to be "nonretributional" but mandatory Fitness Improvement Training (FIT) can impact ability to perform TDY's, thus the ability to perform one's job, as well as informal policies restricting job promotion if not meetng standards (13).

In summary, after reviewing the make-up of both impact and acceleration panels at Armstrong Laboratory and the comparable screening factors used for operational pilots, we recommend that efforts be made to: 1) standardize the aeromedical data captured for pilots and subjects; 2) develop a process for establishing interrater reliability for reading spinal (thoracolumbar and cervical) x-rays; and 3) develop a process for compartmentalizing potentially grounding information if gathered in a research protocol so that it can be used for research but not for grounding the pilot. If performance metrics are part of the protocol, such as tracking tasks under sustained acceleration, then the psychological state of the subject/pilot may be an important cofactor, but it is much less likely to affect biodynamic responses under impact acceleration conditions.

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